



UNIVERSITI PUTRA MALAYSIA

**ACOUSTIC PROPERTIES OF LOW DENSITY OIL PALM
(ELAEIS GUINEENSIS JACQ) FIBREBOARD**

SEMSOLBAHRI BOKHARI

FH 2000 5

**ACOUSTIC PROPERTIES OF LOW DENSITY OIL PALM
(*ELAEIS GUINEENSIS* JACQ) FIBREBOARD**

By

SEMSOLBAHRI BOKHARI

**Thesis Submitted in Fulfilment of the Requirements for the
Degree of Master Science in the Faculty of Forestry
UNIVERSITI PUTRA MALAYSIA**

March 2000



Dedicated to my loving parents, brothers, sisters,
and my special friend, Mus. M



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in
fulfilment of the requirements for the degree of Master Science

**ACOUSTIC PROPERTIES OF LOW DENSITY OIL PALM (*ELAEIS*
GUINEENSIS, JACQ) FIBREBOARD**

By

SEMSOLBAHRI BOKHARI

March 2000

Chairman : Mohd. Ariff Jamaludin, Ph.D.

Faculty : Forestry

An ultrasonic test was carried out to determine the acoustic properties of low density oil palm fibreboard. The main objective of this study was to investigate the suitability of using oil palm empty fruit bunches (EFB) as partial replacement for the acoustic materials in audio room.

The board was manufactured by using rubberwood (*Hevea brasiliensis*) and oil palm (*Elaeis guineensis*, Jacq). The rubberwood was used as the control. Three levels of board density and five thicknesses were used to investigate the relationship of acoustic parameters (wave velocity and attenuation coefficient) to these independent variables. In

addition, this study consisted of two sub-studies; (i) the effect of resin content on the acoustic properties, and (ii) the trend of pulse velocity travelling through the boards of different thicknesses.

The result showed that the acoustic properties of oil palm boards were significantly affected by a variation in board densities and thicknesses, as well as resin content. On the other hand, it was found that the velocity of pulse was influenced by the variation in the resin content, thickness and density of the boards.

The pulse velocity, which travels through the EFB, was similar to that of rubberwood boards, suggesting that the acoustic properties of EFB were in the same class as that of rubberwood. The board with 12 mm thickness was found to be able to absorb more pulse wave than the board of other thicknesses for each type of board density.

Based on the result, the low density oil palm fibreboard was suitable to be used as a core layer for building a wall in audio room. However, it needs further improvement on its design and structure to have a better performance as the absorbent materials. This study also found that the ultrasonic test could be a good non-destructive test method to assess the acoustic properties.

Abstrak thesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

**SIFAT AKUSTIK PAPAN GENTIAN BERKETUMPATAN RENDAH
DARIPADA TANDAN KELAPA SAWIT (*ELAIS GUINEENSIS*, JACQ)**

Oleh

SEMSOLBAHRI BOKHARI

Mac 2000

Pengerusi: Mohd. Ariff Jamaludin, Ph.D.

Fakulti: Perhutanan

Kajian ini telah menggunakan ujian ultrasonik bagi menentukan sifat bunyi papan gentian berketumpatan rendah. Objektif utama kajian ini dijalankan adalah untuk mengenalpasti kesesuaian penggunaan papan gentian daripada tandan kelapa sawit (EFB) sebagai pengganti separa untuk bahan akustik di dalam bilik audio.

Papan gentian tersebut telah dihasilkan daripada dua jenis bahan mentah iaitu gentian kayu getah (*Hevea brasiliensis*) dan gentian kelapa sawit (*Elaeis guineensis*, Jacq). Papan gentian daripada kayu getah dijadikan sebagai kawalan dalam kajian ini. Tiga jenis ketumpatan papan dan lima jenis ketebalan yang berlainan telah dihasilkan bagi setiap jenis bahan tersebut untuk memahami hubungan antara variasi ini dengan parameter-parameter sifat akustik bahan (halaju dan

amplitud gelombang bunyi). Kajian ini mengandungi dua lagi sub-kajian iaitu (i) kesan perekat yang digunakan ke atas sifat akustik dan (ii) sifat halaju gelombang bunyi terhadap variasi ketebalan papan gentian tersebut.

Hasil kajian ini mendapati bahawa, amplitud tekanan bunyi (attenuation coefficient) telah dipengaruhi oleh ketumpatan dan ketebalan papan. Manakala, halaju nadi (pulse velocities) pula telah dipengaruhi oleh variasi kandungan bahan perekat, ketebalan dan ketumpatan papan gentian ini.

Halaju nadi bagi papan gentian daripada kelapa sawit adalah sama dengan halaju nadi bagi papan gentian getah. Ini bermakna bahawa, sifat akustik bagi gentian kelapa sawit berada di dalam kelas yang sama dengan gentian kayu. Keputusan kajian juga menunjukkan bahawa papan gentian berketebalan 12 mm mampu menyerap lebih banyak gelombang bunyi berbanding dengan papan gentian dari ketebalan yang lain.

Berdasarkan kepada keputusan dalam kajian ini, papan gentian berketumpatan rendah daripada kelapa sawit adalah sesuai untuk dijadikan bahan penebat bunyi pada dinding sebuah bilik audio. Namun, ia memerlukan sedikit peningkatan dari segi stuktur dan reka

bentuk untuk dijadikan bahan penebat bunyi yang lebih baik. Kajian ini juga mendapati bahawa ujian ultrasonik amat sesuai digunakan dalam menentukan sifat akustik dan juga sifat kekenyalan bahan.

ACKNOWLEDGEMENTS

First of all, the author would like to express his gratitude to the respected advisor and chairman of this study, Dr. Mohd. Ariff Jamaludin. Appreciation is also directed to the other committee members, Dr. Paridah Md. Tahir, Dr. Mohd. Pauzi Ismail, Dr. Wong Ee Ding and Prof . Madya Dr. Mohd. Zin Jusoh, for their advice and support throughout the study.

Secondly, the author would like to express his appreciation to Mr. Ridzuan Ramli of Palm Oil Research Institute of Malaysia (PORIM), Mr. Harmaen Ahmad Saffian and Mr. Abd. Jalal Aman of the Faculty of Forestry, Universiti Putra Malaysia (UPM), and Mr. Yong Foo Onn of Forest Research Institute Malaysia (FRIM), for their assistance and advice during the entire board making process.

Finally, special gratitude is due to Malaysia Adhesives & Chemical Sdn. Bhd. (MAC) and PORIM in supplying the raw materials for the board making in this study. Thanks are also directed to the staff members of Malaysia Institute of Nuclear Technology (MINT), for kindly allowing the author to use the instrument for ultrasonic tests.

I certify that an Examination Committee met on 29 March 2000 to conduct the final examination of Semsolbahri Bokhari on his Master of Science thesis entitled "Acoustic Properties of Low Density Oil Palm (*Elaeis guineensis*, Jacq) Fibreboard" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of The Examination Committee are as follows:

WONG EE DING, Ph.D.

Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

MOHD. ARIFF JAMALUDIN, Ph.D.

Faculty of Forestry
Universiti Putra Malaysia
(Member)

MOHD. PAUZI ISMAIL, Ph.D.

Malaysia Institute of Nuclear Technology
(Member)

PARIDAH MOHD. TAHIR, Ph.D.

Faculty of Forestry
Universiti Putra Malaysia
(Member)

MOHD. ZIN JUSOH

Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Member)



MOHD. GHAZALI MOHAYIDIN, Ph.D.
Professor/Deputy Dean of Graduate
School
Universiti Putra Malaysia

Date: **26 MAY 2000**

This thesis was submitted to the Senate of Universiti Putra Malaysia and was accepted as fulfilment of the requirements for the degree of Master Science.



Kamis Awang, Ph.D.
Associate Professor/Dean of
Graduate School
Universiti Putra Malaysia

Date: 13 JUL 2000

DECLARATION

I hereby declare that the thesis is based on my work except for quotations and citations which have been duly acknowledged. I also declare that this thesis has not been previously or concurrently for any other degree at UPM or any other institutions.

Signed



(SEMSOLBAHRI BOKHARI)

Date: 25 May 2020

TABLE OF CONTENT

	PAGE
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL SHEETS	x
DECLARATION FORM	xi
LIST OF TABLES	xiv
LIST OF FIGURES	xv
LIST OF PLATES	xvii
LIST OF ABBREVIATIONS	xviii
 CHAPTER	
I INTRODUCTION	
Acoustic Properties of Wood	1
Ultrasonic Determinations	2
Problem statement	2
Objectives	3
 II LITERATURE REVIEW	 4
Acoustic Properties of Material	4
Definition of Acoustic	4
Room Acoustic	4
What is Ultrasound	5
An Application of Ultrasound	6
Principle of Ultrasonic Testing	7
Principle of Transducers	10
Ultrasonic Wave in Solid Material	10
Wave Propagation in Anisotropy Material	11
Sound Wave Attenuation	12
Fundamentals of Attenuation Coefficient	14
Dissipation Factor (Q)	17
Sound Reflection and Refraction	19
Sound Transmission Phenomena	20
Reflection and Transmission Fundamentals	22
Evaluation of Wood Based Composite Using	
Ultrasonic Method	26



III	METHODOLOGY	30
	General	30
	Board Manufacturing	31
	Fibre Preparation	31
	Type of Adhesive Used	31
	Board Density and Thickness	31
	Cutting of Test Specimens	32
	Application of Ultrasonic Test	32
	Equipment	32
	Couplant	35
	Data Collection	35
	Data Calculation	36
	Data Analysis	39
IV	RESULTS AND DISCUSSION	40
	Factors Affecting the Pulse Velocity	41
	Effect of Board Density	41
	Effect of Board Thickness	42
	Acoustic Properties of Low Density Fibreboard	45
	Effect of Raw Material on the Acoustic Properties	46
	Effect of Board Densities on the Acoustic Properties	48
	Effect of Board Thickness on the Acoustic Properties	53
	Effect of Resin Content on the Acoustic Properties	57
	Selection of End Product from Low Density Oil Palm Empty Fruit Bunches Fibreboard	59
V	CONCLUSION	60
	REFERENCES	63
	APPENDIX	
	A Data Calculation from Ultrasonic Test	69
	B Experimental Procedure of Ultrasonic Test	71
	C Prediction of MOE from Ultrasonic Test	75
	VITA	84

LIST OF TABLES

TABLE	PAGE
2.1 Transmission Loss for Solid Wall Materials	22
4.1 Factor Affecting the Pulse Velocity	41
4.2 Analysis of Variance on Acoustic Properties of Low Density Fibreboard	46
4.3 The Effect of Raw Material on Acoustic Properties of Low Density Fibreboard	47
4.4 Effect of Density on the Acoustic Properties of Low Density Fibreboard	48
4.5 The Effect of Board Thicknesses on the Acoustic Properties of Low Density Fibreboard	54
4.6 The Effect of Resin Content on the Acoustic Properties of Low Density Fibreboard	58
A1 Data of Rubberwood Reconstituted Boards	69
A2 Data of Oil Palm Reconstituted (EFB) Boards	70
C1 Analysis of Variance of Modulus of Elasticity	76
C2 Summary of Linear Regression Analysis of MOE, Density and Velocity	81

LIST OF FIGURE

FIGURE	PAGE
2.1 Propagation of Stress Wave by Elctrical Pulse Generator	9
2.2 Propagation of a Stress Wave in a Bar by Pendulum/Impactor Method	9
2.3 Reflection and Refraction at the Boundary between two Materials	20
2.4 Sound Reflection and Transmission through a Layer	21
2.5 Reflection and Transmission of a Plane Wave at a Boundary	23
3.1 Illustration of the Amplitude from Oscilloscope	38
4.1 The Trend of Pulse Velocity with Respect to Densities of Boards	42
4.2 Effect of Variation Board Thicknesses onto Pulse Velocity	43
4.3 Trend of Pulse Velocity Travel through Low Density Fibreboard	44
4.4 The Attenuation of Pulse Wave Traveled through the Boards at Different Type of Raw Material	48
4.5 The Trend of Pulse Attenuation through the Samples	49
4.6 The Trend of Pulse Attenuation in EFB Samples	50
4.7 Phenomena of Pulse Wave Movement in Compact Samples	51

4.8	Phenomena of Pulse Wave Movement in Low Density Samples	52
4.9	The Trend of Reflected Wave through Various Board Densities	53
4.10	The Distribution of Attenuation Coefficient by Board Thickness	55
4.11	Trend of Transmitted Wave through EFB Low Density Fibreboard	56
4.12	The Distribution of Reflected Wave	57
4.13	The Variation Effect of Resin Content to the Acoustical Properties	58
B1	The Diagram for Ultrasonic Test	71
B2	The Connection of Pulse Generator to Transducers	72
B3	The Design of Transducers	72
B4	Arrangement of Transducers for Direct Transmission	73
B5	Transmission of Pulse Wave through the Samples	74
C1	The Distribution of MOE by Boards Densities	77
C2	The Variation Value of MOE According to the Thickness of Samples	78
C3	The Effect of Resin Content to the MOE of Boards	78
C4	The Regression Analysis of MOE and Squared Pulse Velocity	80
C5	Linear Regression between MOE and Densities of Boards	80

LIST OF PLATE

Plate		Page
3.1	The Set-up of PUNDIT to other Equipment for Ultrasonic Test	33

LIST OF ABBREVIATIONS

σ	Stress Wave
ρ	Density of Materials
θ	Angel of Sound Source and Reflection
v	Pulse Velocity
α	Attenuation Coefficient
λ	Distance per Cycle of Pulse Wave
β	Diffraction Angel
ω_r	Instantaneous Energy System
δ	Logarithmic Decrement; Harmonically oscillating System
σ_{n+1}	Amplitudes of Two Consecutive Cycles
f	Frequency Used for Testing
W	Energy Loss per Cycle
Q	Dissipation Factor
N	Newton
Z_i	Sound Impedance
dB	Decibels;
t	Transit time of Pulse
v	Volume
g	Gravity Acceleration
MOE	Modulus of Elasticity
PORIM	Palm Oil Research Institute of Malaysia
MINT	Malaysia institute of Nuclear Technology
PF	Phenol Formaldehyde
TL	Transmission Loss

CHAPTER I

INTRODUCTION

ACOUSTIC PROPERTIES OF WOOD

Wood and oil palm are both cellulosic materials. Thus, the acoustic properties of oil palm fibres (empty fruit bunches, trunk and frond) could be similar to wood. The acoustic properties of wood vary with anatomy, density, moisture content and the temperature of the surrounding atmosphere (Bootle, 1971; Schiewind, 1989). The ability of a material to absorb sound is dependent on its mass. That is, the way it is fixed, and the acoustic properties of the surface of the material (Warnock, 1990; Desh and Dinwodie, 1983; Parkin et al. 1979;) i.e, whether the surface is capable of absorbing or reflecting sound (gluing and surface coating for wood) (Schultz, 1969; Bucur, 1986; Kollmann, 1969).

However, there is no documentation on the acoustic properties of oil palm fibreboard. Thus, this study was carried out to evaluate the acoustic properties of low density oil palm fibreboard, and to compare their acoustic properties to the rubberwood fibreboard.

ULTRASONIC DETERMINATIONS

The ability of ultrasound to measure and monitor micro-structure related properties has been established in the laboratory. Invariably, two of the propagation parameters that are used in the ultrasonic determination of a material are attenuation and sound wave velocity (Serabian, 1986). The two principle causes of attenuation are scattering and absorption. The latter are intrinsic to the particular combination of material and processes under consideration. Absolute quantitative relations are usually unavailable, therefore, empirical material property-ultrasonic parameter correlation based upon qualitative reasoning are sought. According to Vary (1987), velocity measurements are useful for measuring elastic constant, residual stress, and density.

PROBLEM STATEMENT

The acoustic properties of commercial wood species such as rubberwood have been documented in the last few years (Chew et. al. 1981). However, there is no documentation on the acoustic properties of oil palm. Therefore, it is important to document its acoustic properties so that its potential for musical instruments and acoustic building materials can be explored.

In this country, direct method (reverberation room test) could not be used to test the acoustic properties of a material because of the appropriate equipment is not available. Furthermore, the available direct method needs large samples and are very costly. Hence, this study used the indirect method to determine the acoustic properties of low density oil palm fibreboard, which is ULTRASONIC, a non-destructive test (NDT). A direct transmission principle was used to measure the amplitude and transit time of pulse that travel through the samples in order to determine their acoustic properties.

OBJECTIVE

The main objective of this study is to evaluate the acoustic properties of oil palm fibres. And to propose the potential end uses of low density oil palm fibreboard.

The specific objectives of this study were:

1. To identify the factors affecting the acoustic properties of low density oil palm fibreboard.
2. To understand the trend of pulse velocity that travel through various board thicknesses.
3. To compare the acoustic properties of low density oil palm fibreboard to wood fibreboard.

CHAPTER II

LITERATURE REVIEW

ACOUSTIC PROPERTIES OF MATERIAL

Definition of Acoustic

The concept of energy and pressure are essential in understanding the applications of acoustic. Generally, acoustics is the science of sound, which includes its distribution, and absorption of sound wave by materials (Ahmad Khan, 1990; Pierce, 1998). One of the essential features of sound is pressure. The feature that is always associated with sound vibration of materials particles (Porgess, 1977) is known as sound pressure. Pressure is transferred from one vibrating particle to the next, and acoustic pressure always travels through the medium as a wave (Hopper, 1969; Leslie et al. 1985; Michael, 1993; James, 1994).

Room Acoustic

In a room, those for direct listening, natural signals are used and picked up directly by the ear of the listener. The radiation and reception processes take place in the same enclosure; these processes are adjacent in space and time (Nelson, 1973). A principal characteristic

of this nature is that the power of the sound source employed in them is comparatively small (Manskovy, 1971) and is confined by the limitation of human voice and musical instrument.

Room acoustic is concerned with sound propagation in enclosures where the sound-conducting medium is bonded on all sides by walls, ceiling, floor and furnishing (Kuttruff, 1990; Dunlop, 1980; Pollard, 1977). This boundary usually reflects a certain fraction of the sound pressure impinging onto them. Another fraction of the pressure is absorbed. This latter pressure is extracted from the sound field inside the room either by conservation into heat or by being transmitted to the outside by the walls (James, 1994). The combination of the numerous reflected components and un-reflected wave are responsible for what is known as 'the acoustics of a room' and also for the sound field in a room (Kuttruff, 1990).

What is Ultrasound?

'Sound' is due to a stream of 'atom' emitted by the sounding body (Lyle, 1978). The speed of this atom after being emitted or propagated are known as velocity of sound then, the number of emitted atom per unit of time is the frequency of sound wave. There are three types of frequencies disturbances; the low disturbances of frequencies (infrasound) which is

too low to be heard by human ear. Secondly, is audible sound which is can be heard by human, this sound wave ranging 20 Hz to 20 kHz (Quote: Mohd. Pauzi). Finally, the higher disturbance of frequencies is known as ultrasound, which is too high to be heard by human ear. The frequencies of ultrasound are above 20 kHz (Pierce, 1998).

According to Kuttruff (1991), ultrasound can be thought of as analogous to ultraviolet light in that it characterises region of acoustic phenomena which is not accessible to human perception, because of the high frequencies involved.

An Application of Ultrasound

Any kind of sound in contrast to electromagnetic waves can only be propagated in a material medium. Its velocity is strongly influenced by that medium, and its attenuation depends on the nature of the medium (Alex et al. 1987). Hence, if these quantities are known from a measurement, conclusion can be drawn concerning the physical properties of the medium.

Ultrasonic is a name given to the study and application of ultrasound which is the sound of a pitch too high to be detected by the human ear (frequencies greater than 20 kHz). According to Blitz and Geof